Math and Science Teacher Leadership Development:
Findings from Research and Program Reviews

BSCS Technical Report No. 2017-03

A Report of
The Developing Math/Science Teacher Leadership: A Consensus Approach to Evaluating Program Quality and Supporting Teacher Leader Workforce Development Project

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A report of the *Developing Math/Science Teacher Leadership: A Consensus Approach to Evaluating Program Quality and Supporting Teacher Leader Workforce Development Project*, a collaboration of BSCS, the Knowles Teacher Initiative, and the Education Development Center

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Recommended citation:
Galosy, J., Mohan, L., Mohan, A., Miller, B., & Bintz, J. (2017). *Math and science teacher leadership development: Findings from research and program reviews* (Research Report No. 2017-03). Colorado Springs, CO: BSCS.

This work was supported by a grant from the National Science Foundation (grant number 1534698)., Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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1. Overview

The overall goal of this synthesis project's research and program review was to identify program attributes that support math and science teacher leadership development. We define a teacher leadership program as a discrete set of organized learning opportunities, with a finite duration, purposefully designed to prepare math and/or science teachers for formal or informal teacher leadership roles. By teacher leadership, we mean: *"the practices through which teachers—individually or collectively—influence colleagues, principals, policy makers, and other potential stakeholders to improve teaching and learning"* (Holland, Eckert, & Allen, 2014, p. 435). The review does not include teacher leadership development that takes place outside of programs. We recognize that teachers can, and do, put together their own ad-hoc mix of activities, courses, or experiences that help them develop leadership capabilities. For example, they might read a book about instructional coaching in mathematics, attend a workshop at a science teachers' conference on helping teachers implement the Next Generation Science Standards, or learn from a colleague how to facilitate a teacher study group. However, given the project goals and research questions, we limited our search specifically to teacher leadership development efforts designated as programs.

For comparative purposes, we classified teacher leadership programs included in the literature and program reviews using a framework developed by Lukacs and Galluzzo (2014). The authors looked at teacher leaders' roles in reform efforts historically and proposed three teacher leadership models that reflect varying degrees of teacher agency, ownership, and authority. In the original model (Model One), teachers are recipients and implementers of reform strategies. Teachers learn a strategy from reform designers (often university researchers) and implement it in their classrooms. In Model Two, which has emerged during the last two decades, teachers assume leadership roles that traditionally have been the principal's domain, particularly instructional leadership. Teacher leaders formally or informally facilitate their colleagues' professional learning (as coaches, mentors, committee chairs, and so forth) with little or no input into the instructional vision itself. Model Three, which is just beginning to gain traction, positions teachers as change agents who not only improve their own classrooms but also drive continuous improvement in their schools and beyond.

To explicate Model Three, Lukacs and Galluzzo (2014) offer a comparison between teachers as implementers of others' reform ideas and teachers as change agents:

> We argue the difference can be seen when comparing the teacher who returns from the latest meeting of the school improvement committee and says, "Here's what we have to do next," with the one who initiates a literacy program for recent immigrant families in the school and seeks external funding to get it started. While the former is arguably a teacher leader, she/he is not necessarily actively working to improve the school with the agency, creativity, and license of the latter (p. 103).

The authors go on to make the point that teachers, who are the closest to student learning, are best positioned to take up continuous improvement work. Teachers "have areas of expertise that allow them to take initiatives in a 'bottom up' design with the school as the unit of change" (p. 103). In this vision of teacher leadership, which is still taking shape, teachers are the ones driving change within and beyond their classrooms.

Given our project's goal of strengthening teacher workforce capacity, Lukacs and Galluzzo's (2014) three models are useful for examining math and science teacher leadership development from a systems perspective. These three models offer a framework for examining what kind of leadership work the math and science programs included in this review prepare teachers to assume. The models do not have perfectly clear boundaries, so assigning programs to a model is not an exact science. The purpose here is not to set the models up against each other. The work of educational reform requires the contributions of all involved.

There is certainly a need for those located outside of classrooms to share their ideas and support those who teach students every day. However, if continuous improvement is the goal, a teacher workforce with the commitment, professional judgment, and collective authority to drive improvement efforts is essential (Hargreaves & Fullan, 2012; Lukacs & Galluzzo, 2014).

In order to gauge capacity for continuous improvement, we categorized programs into the three models. None of the programs included in the review matched Model One. By definition, Model One programs solely support teachers in enacting reforms with their own students. These types of programs do not fit the definition of teacher leadership, described above, used for the review selection process.

The majority of programs fit Model Two (instructional leadership), although there was variability in the agency and autonomy teachers had for leading improvement. We also looked for differences in program descriptions and findings between Model Two and Model Three programs.

This review is divided into two major sections. The first examines peer-reviewed research of math and science teacher leadership development. The second section focuses on math and science teacher leadership programs with publicly available evidence of effectiveness (e.g., peer-reviewed publication or eternal evaluation report).

2. Research on Mathematics and Science Teacher Leadership Development

The purpose of this section is to share current research on math and science teacher leader development acquired from published work in peer-reviewed journals. The research literature review included research from 2009 to the present building on the *MSP Knowledge Management and Dissemination* literature reviews conducted in 2009 and 2010 (e.g., Schiavo, Miller, Busey, & King, 2010a). The search for research yielded close to 89 potential research studies based on keywords and abstract descriptions alone, of which 18 met eligibility requirements when examined closer (see Objective 1 description in Appendix A). Most of the original studies did not satisfy the eligibility criteria for the following reasons:

- The study did not focus on the *development* of teacher leaders but rather on impacts of teacher leaders in schools.
- The study was not specific to math, science, or STEM teacher leader development.
- The study was a program evaluation that was not peer reviewed or not an external evaluation report.
- The article was a theoretical piece without a research question and a defined data set.

The limited number of empirical studies available is in line with other literature reviews on the same topic. Schiavo, Miller, Busey, and King (2010a) found only 25 research studies and evaluation reports to meet similar criteria from 1991 spanning up to 2009. Of these 25 studies, only eight investigated the relationship between the design of the program and teacher leader outcomes. Additionally, in a recent publication by Wenner and Campbell (2017) 54 studies published between January 2004 and December 2013 met criteria for high quality empirical research on teacher leadership. Among the 54 studies, only seven focused on math and science teacher leadership. When looking at development of teacher leaders only, that number shrinks.

The eligible peer-reviewed research studies were examined and coded based on their definitions of teacher leadership, their research goals and methods, the program structure, the program design principles, the strategies and skills developed among teachers, and the research findings. This review compares the research studies in each of these areas, focusing mainly on notable patterns and gaps and concluding with general findings gleaned from the review process.

Teacher Leadership Definitions and Roles

The teacher leaders recruited for the research studies were primarily those that had well-defined roles in their schools or districts, such as professional development facilitators, coaches, or mentors (14 studies; 78%). Selecting participants with distinct roles makes sense given the nature of recruitment processes for research studies. Moreover, seven of these 14 studies documented teacher leader development during efforts to scale up a reform-based curriculum, which required teacher leaders to facilitate professional development in their schools and districts. When we map these 14 research studies to Lukacs and Galluzzo's (2014) descriptions of teacher leadership, the role teacher leaders play aligns closely to Model Two. The teacher leader participants, described as accomplished teachers, help the researchers and school administrators initiate a reform effort developed by outsiders to the school community. The teacher leaders may be enthusiastic advocates of the reform initiatives, but there is an expectation that they closely align their work with the reform effort itself (i.e., fidelity) with some agency to adjust the program given their school climate. Thus, researchers and administrators develop the vision for the district, and teacher leaders are key personnel to advocate for and deliver the reform to their colleagues.

The other four research studies document the development of teacher leaders in undefined, informal roles in their school communities. These studies describe teacher leaders as agents of change in their communities, with each teacher leader pursuing notably different leadership activities depending on his or her community and school circumstances and his or her passions for educational reform. The teacher leaders initiate reform efforts, seeking support from colleagues and administrators. These studies provide a glimpse at Model Three from Lukacs and Galluzzo's (2014) framework, in which the teacher leaders are "actively working to improve the school with the agency, creativity, and license" (p. 103).

Looking at the researchers' definitions of teacher leadership only, it is clear that most researchers hold a view of teacher leadership that extends well beyond the role they had teacher leaders carry out in the studies. Most of the studies articulate a vision of teacher leadership more in line with Model Three; however, only eight of the 18 studies describe the teacher leader role as one that is beyond facilitators and coaches (i.e., Model Two). Although support for Model Three seems unequivocal among researchers, there may be additional design factors and constraints that inhibit research in this area at present. Scalability studies, for example, require a well-defined program with clear guidance on how to enact the curriculum to achieve the intended results. To meet these requirements, researchers inevitably must control the conditions around enactment. Fidelity, therefore, is a key factor to monitor large-scale implementation efforts. Given the need for fidelity, teacher leaders playing a role in scalability studies have limited agency and are naturally fulfilling teacher leader roles more in line with Model Two.

Research Goals and Methods

This section reviews similarities and differences between the research goals and methodology of Model Two and Model Three studies. In the 14 studies that align with Model Two, 11 studies have research goals targeting teacher leaders' growth in the facilitation of professional development workshops, coaching, and mentoring activities. Model Three research studies, however, have research goals to expand teachers' identity as leaders and to empower teachers to engage in leadership activities in their unique way. It is important to note that three of the 14 Model Two studies also had research goals to examine identity development as teacher leaders learn to implement a particular science program in their home districts. Table 1 includes examples of research goals organized by model type.

Table 1. Research Goals by Model

Model	Number of studies	Example research goals
Model Two	11	1. What forms of PD practice (specific to the three goals for the math leaders' learning outlined above) did the math leaders develop over the course of the design study? 2. What does the math leaders' development imply for the revision of our conjectures regarding the goals for their learning and means of supporting their learning? *from Jackson et al., 2015*
	3	1. How do teachers define leadership within their own professional contexts? 2. What kinds of activities do teachers consider to be leadership [activities]? 3. In what ways do teachers perceive themselves as leaders? *from Hanuscin et al., 2012*
Model Three	4	1. How do Knowles Science Teaching Foundation (KSTF)-supported teachers' retention rates compare with rates reported in the literature? 2. What do these early career teachers perceive as the most important learning opportunities for their growth and sustainability as secondary mathematics and science teachers? 3. How do the learning opportunities they identify support their growth and sustainability? *from Galosy & Gillespie, 2013*

The research methods did not distinctly differ by model type, with most studies using qualitative research methodologies, notably phenomenology, case studies, and design studies. Some studies augment their qualitative data with quantified measurements of classroom practice or teacher leader perceptions, used for descriptive purposes. Three studies use inferential statistics to measure change: (1) Yow and Lotter (2016) measured change in classroom practice; (2) Koellner and colleagues (2011) measured growth in knowledge and pedagogical content knowledge from pre to post, comparing teacher leaders and their fellow teachers; and (3) Roesken-Winter and colleagues (2015) gathered pre, post, and six months post on teacher leader competencies, including content knowledge. No study employed a controlled experiment measuring impacts of particular program attributes on teacher leader development. The qualitative data and analysis, however, provides compelling evidence of program attributes that are essential to teacher leader development, which will be taken up in the findings portion of this review.

One study included in this review warrants additional explanation—that is, Larkin and colleagues (2009). This study is an ethnography of a science department with an alternative approach to secondary science education. The vision for the program and the curriculum described by Larkin and colleagues emerged from a distributed leadership model among a group of science teachers who continued to work together over several decades. Larkin and colleagues provide a unique perspective looking at the natural occurrence of Model Three leadership driven completely by teacher leaders at one school over a span of decades.

Program Structure for Teacher Leadership Development

The research studies use different program structures in different contexts: single or multiyear institute program (10 studies[1]), academic/credit program (4), design study (3), professional learning community program (2), seminar program (1), and internship program (1). Table 2 organizes the research studies based on their model type and program structure. One program, the Knowles Science Teaching Foundation (KSTF) Fellows (Galosy & Gillespie, 2013), relied on both the institute structure and the professional learning community (PLC) structure. The Problem-Solving Cycle (Borko et al., 2014; Koellner et al., 2011) also relied on two structures—the institute structure and design study. With one exception, researchers did not justify their choice of program structure. Green and Kent (2016) articulated their case for using the internship program for teacher leader development, which required teacher leaders to take a year away from their teaching positions to engage in internship activities at the regional Math, Science, and Technology Initiative (MSTI) center. The program structure allowed the teacher leaders to participate as learners of the MSTI program and to shadow veteran MSTI specialists on the job.

It is not surprising that the summer institute is the dominant structure utilized by researchers given the availability of teacher leaders at that time of year. All the research programs using the institute structure included subsequent school year contact with teacher leaders but in a reduced capacity. Most of the development activities occurred during the intensive summer institutes, also called academies.

The professional learning community structure (used by Galosy and Gillespie [2013] and naturally occurring with Larkin and colleagues [2009]) encouraged teacher leaders to have regular structured contact with each other during the school year to participate in reflective practice with one another. Likewise, the seminar structure found in the work by Elliott and colleagues (2009) also focused on regular contact with teacher leaders during the school year, but unlike the PLC model, the teacher leaders engaged with research-based practices through readings and videos. The seminar structure was designed to increase teacher leaders' knowledge of research-based practices, while the PLC structure was designed so that teacher leaders presented and reflected on each other's classroom practice.

In the review, we identified a discrete list of program structures used for teacher leader development activities, but we still know little about the benefits and drawbacks of each structure and how the program structure itself may influence the outcomes for teacher leaders. For example, one might question how the institute model with minimal school year contact with teacher leaders compares to a PLC or seminar model that has regular structured contact with teacher leaders as they are in the midst of their practice. Another might question whether the internship program significantly benefits the teacher leaders in ways not accomplished by other program structures. Researchers have yet to tap into questions investigating how program structure relates to development outcomes for teacher leaders. While it is likely that researchers can articulate their decisions for the chosen program structure citing both affordances and constraints of the design, uncertainty remains about whether the structure of the program influences teacher leader development.

[1] Numbers in parentheses refer to the number of research studies with that characteristic.

Table 2: Structure, Design Principles, and Strategies and Skills

				Structure						Design principles										Strategies, skills, and other development activities														
	Research study	Program / Project	Math (M) or Science (S)	Institutes / academies	Academic / credit	Design / workshop	PLC	Seminar	Internship	Content deepening / coherence	Pedagogical content deepening	Pedagogical investigation / inquiry	Sustained professional engagement	Growing leadership capacity / identity	Promoting collaboration / community	Reflective practice	Professional knowledge for design	Pressing professional knowledge	Adult learning	Theoretical readings	Content / inquiry task engagement	Analysis of video / classroom practice	Analysis of student work / ideas	Analysis of curriculum / lessons	Lesson planning	Workshop planning	Observing experts	PD facilitation skills	Coaching skills	Teaching skills (with students)	Reflection activities	Leadership goals/ leadership plan	Online discussions / blogs	Other
Model Two	Yow & Lotter (2016) Lotter et al. (2014)	Inquiry-oriented teaching	M	●						●	●				●						●			●			●	●		●	●			
Model Two	Elliott et al. (2009)	Researching Mathematics Leader Learning (RMLL)	M					●			●	●						●			●	●	●			●		●						
Model Two	Green & Kent (2016)	Math, Science, and Technology Initiative (MSTI)	M S						●	●	●			●										●	●		●		●					
Model Two	Jackson et al. (2015)	Connected Math Project 2 (CMP2)	M			●						●	●	●	●	●	●	●	●			●				●	●	●			●			●
Model Two	Borko et al. (2014)	Problem-solving cycle (PSC)	M	●		●				●	●	●		●	●	●	●				●	●	●			●		●			●			
Model Two	Koellner et al. (2011)	Problem-solving cycle (PSC)	M	●		●				●	●	●				●					●	●	●				●	●			●			
Model Two	Singh et al. (2012)	Iowa Chautauqua	S	●							●			●						●	●													
Model Two	Roeskin-Winter et al. (2015)	DZLM- CPD for math in Bundesland	M		●					●	●	●	●		●	●	●			●	●										●		●	●
Model Two	Kuzle & Biehler (2015)	DZLM- statistics tools for teachers	M		●					●	●						●		●	●						●	●	●			●			
Model Two	Koballa et al. (2010)	Science Mentors in Training (SMIT)	S	●							●	●			●	●			●	●							●		●				●	●
Model Two	Hanuscin et al. (2014) Hanuscin et al. (2012) Rebello et al. (2011)	Leadership in Freshmen Physics / Physics First	S	●						●	●			●		●				●	●										●	●	●	●
Model Three	Yow (2010)	M.Ed. Program	M		●					●	●			●	●					Not enough detail to determine														
Model Three	Hunziker et al. (2012)	M.Ed. Program (STEM)	M S		●					●	●	●		●	●	●				Not enough detail to determine														
Model Three	Larkin et al. (2009)	Integrated Science Program (ISP)	S				●					●	●	●	●		●						●	●	●						●			●
Model Three	Galosy & Gillespie (2013)	Knowles Science Teaching Foundation Fellows (KSTF)	S	●			●			●	●	●	●	●	●	●	●	●			●		●	●							●		●	●

*In the sample of 18 research studies, there is overlap in the program under study. When the research studies pursue different research questions and include different data sets, we treat each published paper as a distinct research study even if the program under review is the same. Table 2 combines the research studies when the studies share a common program but different research studies.

Program/Project Design Principles

The research studies use a diverse set of design principles to guide their teacher leader development programs and research interventions. The design principles appear to have little connection to the model type or program structure. Researchers cite the lack of program design principles available in the research literature on teacher leadership and therefore drew on research-based principles for professional development more generally. For example, Jackson and colleagues (2015) summed up the challenge saying, “within mathematics education and PD research more broadly, minimal attention has been given to how to support PD leaders in designing and facilitating high-quality PD .... Given the thin research base, we extrapolated from the literature on high-quality teacher PD and pre-service teacher education when designing supports for math leaders’ learning” (p. 94). Several researchers note the same experience and use design principles from teacher education as opposed to teacher leader development. For example, some of the five core features by Desimone (2009) were widely cited by researchers as relevant design principles for teacher leader professional development (i.e., these include content focus, active learning, coherence, sufficient duration, and collective participation, although duration was not mentioned as often in the design portion of the studies).

Table 2 includes the main design principles articulated by researchers. Our coding of the research studies represents a conservative classification of principles, including only those principles the researchers wrote about explicitly. For example, it is likely that each study focused on content deepening/subject matter knowledge given the disciplinary focus of their work, yet researchers did not call attention to this principle directly in their description of the design. The design principles that appeared in the studies include content deepening and coherence (10), pedagogical content deepening (13), pedagogical investigation (often with classroom video and data) (9), sustained professional engagement (4), growing leadership identity and capacity (9), promoting collaboration and community (9), reflective practice (8), professional knowledge for design (6), pressing professional knowledge (3), and adult learning theory (3).

Several of the design principles potentially overlap with others, for example, pedagogical investigation, reflective practice, and pressing professional knowledge. Pedagogical investigation includes gathering classroom data—classroom video, student assessments—for analysis of practice. Reflective practice was not particularly grounded in classroom data, although it certainly may have been in some studies. Pressing professional knowledge describes teacher leaders engaging with new theories of education, discourse practices, or other inputs that called into question the status quo of their practice. All three principles engage teacher leaders in inquiry and help them adopt a critical stance toward their practice. It is also the case that most, if not all, research studies supported sustained professional engagement and growing leadership identity and capacity, even if they were not named as design principles directly. Leadership components of the program were generally the least well described.

There is no notable difference between design principles for Model Two and Model Three, however, all Model Three research studies focus on growing leadership capacity and identity.

Most research studies focus on developing content area expertise and pedagogical knowledge among teacher leaders. Several math research studies adopt the Learning Mathematics for Teaching Project’s (2008) *Mathematical Knowledge for Teaching (MKT) Measures*, which includes both subject matter knowledge and pedagogical content knowledge broken down into seven more discrete types of content and curriculum-related knowledge. The research studies in science did not share a similar framework as found across the math studies.

Leadership aspects of the programs were not well described. For example, very few studies directly reference adult learning as a key design principle, which was surprising given its frequent reference as

a notable challenge faced by teacher leaders when working with adult colleagues. While adult learning theory appears to play little role in the design principles (or researchers did not mention it directly), the findings from the research studies suggest it is a recurrent topic of discussion among teacher leaders and one that deserves significant attention in the design of programs.

Strategies, Skills, and Other Development Activities

This section examines what teacher leaders did as part of their participation in the research program. It does not include additional activities teacher leaders completed for research purposes (e.g., interviews, surveys, focus groups, and so forth). The terms "strategies" and "skills" come from the language used in the Teacher Leader Model Standards (e.g., Teacher Leader Exploratory Consortium, 2011, p. 29–30), and the term "activities" comes from Elliott and colleagues (2009). Table 2 lists the strategies, skills, and activities that occurred during teacher leader development programs, with the addition of an "other" category when a strategy, skill, or activity was unique to one study. Given word limitations to research articles, researchers likely did not share the full details and daily schedule for what teacher leaders did during the development sessions. Table 2, therefore, does not represent a comprehensive illustration of each program but rather captures what the researchers focused on in the description of program activities for their published paper. For example, the KSTF Fellows (Galosy & Gillespie, 2013), the M.Ed. programs described by Yow (2010) and Hunziker (2012), the *Iowa Chautauqua* two-week leadership conference in Singh and colleagues (2012), and *Leadership in Freshman Physics* (Hanuscin et al., 2012; Hanuscin et al., 2014; Rebello et al., 2011) give limited details about program activities in the research articles. Our representation of these programs is limited. Two of the programs are included in both the research and program reviews, and more details about program structure and activities are available in the next section (i.e., KSTF, *Leadership in Freshman Physics*).

Due to the limited information about the M.Ed. programs studied by Yow (2010) and Hunziker (2012) and the unique nature of Larkin and colleagues (2009) study, we cannot make comparisons between Model Two and Model Three programs. A unique characteristic of Model Three programs, however, is the emphasis on teacher-chosen leadership activities. Galosy and Gillespie (2013) and Yow (2010) document teacher leaders pursuing various leadership activities depending on their interests. Hunziker (2012) describes teacher leaders conducting action research in their schools. Larkin and colleagues (2009) describe how the contributions made by each teacher leader capitalized on the teachers' strengths and personal assets. The strategies, skills, and activities in these programs likely promoted individualized pursuits of leadership in ways not possible in Model Two programs.

When combining Model Two and Model Three, the strategies, skills, and activities that appear in at least two studies include theoretical or research-based readings (5), content or inquiry task engagement (8), analysis of classroom video (3), analysis of student work and student ideas (5), analysis of curriculum (3), lesson planning (2), workshop planning to conduct professional development with colleagues (4), observing experts modeling a strategy or skill (6), practice with facilitation skills (6), coaching skills (2), structured reflection activities (7), writing leadership goals and developing a leadership plan (2), and participating in online discussions or writing blogs (4). Only one program includes practice teaching with students or other skills and strategies not mentioned widely in the literature.

In the Model Two programs, one of the most common activities in the *math* teacher leader programs is engagement with a mathematical task. Seven of the nine math programs use this approach to content and pedagogical content deepening. Researchers choose mathematical tasks to prompt teachers to wrestle with their mathematical problem-solving abilities and then to participate in discussions with colleagues about the content involved in the work. Moreover, the mathematical tasks led to discussions about

strategies for teaching mathematics to students, student thinking, and potential challenges of using the same or similar problems in the classroom. The mathematical tasks, therefore, anchor most of the teacher leaders' work with content knowledge and pedagogical content knowledge. The *science* programs use a parallel approach engaging teachers in an inquiry investigation that similarly sparks discussion about the content, the science practices involved in the investigation, and how students might engage in the investigation.

The programs also emphasize pedagogical investigations through analysis of video, student work, and/or existing or new curriculum materials. Almost half of the research studies include analysis of classroom data or classroom resources as an essential activity in their program. Hunziker (2012), whose work is not represented well in Table 2, mentions teacher leaders conducting an action research project, which the teachers unanimously agreed was the most important factor influencing their leadership development. The pedagogical investigations allowed the teacher leaders to examine research-based practices in their own practice or realistic settings, fulfilling the teacher leaders' need to stay connected to the realities present when working with young learners.

Researchers also provide teacher leaders with collaborative planning time for the lessons they will teach to students or the workshops they will lead for colleagues. The collaborative planning time along with time to practice facilitation, teaching, or coaching skills gives teacher leaders an opportunity to apply what they learn in a low-stakes environment. Time to apply strategies and skills through collaborative planning or practice sessions occurs in eight of the research studies.

The research studies note that reflection activities are critical components of their programs. Eight of the studies include structured opportunities for reflection. The number rises to 10 when including online discussion forums and blogs. Reflection activities receive mixed reviews from teacher leaders, for example, Hanuscin and colleagues (2014), Roesken-Winter and colleagues (2015), and Kuzle and Biehler (2015) report that a portion of their teacher leaders did not find reflection activities of particular value. For example, Roesken-Winter and colleagues (2015) found only 12.1% of the teacher leaders mentioned self-reflection as an important design principle for developing workshops for their colleagues.

Research Findings

Research studies report different degrees of effectiveness across a range of outcomes for teacher leader development. Given the variety of program structures, design principles, and development activities across the studies, it is challenging to pinpoint specific attributes of the programs as promising ones for teacher leader development. However, it does appear that most researchers agree on the broad dimensions that should be present in development programs. Wenner and Campbell (2017) argue a similar point when faced with only nine studies from their sample of 54 that discussed the programs in enough depth to make confident comparisons between them. They write, "even across these varied organizational structures within which teacher leaders were supported, it was noted that there was relative agreement in the three areas of learning (content knowledge, pedagogical knowledge, leadership skills) that should have been be emphasized within a teacher leadership preparation program" (p. 26). This claim resonates with our analysis, with research findings falling into similar categories but not linked clearly to program attributes.

Findings that show evidence of effectiveness. Researchers report significant positive gains or changes in pedagogical practice, content knowledge and pedagogical content knowledge, and leadership identity and capacity:

- *Improvements in practice.* Eleven of the 18 research studies found changes to teacher leaders' practice as observed in video of classroom teaching (4), video of facilitation of workshops and coaching activities (5), or self-reports of changes in practice (2).
- *Content knowledge gains & pedagogical content knowledge gains.* Only two studies measure content knowledge and pedagogical content knowledge. Koellner and colleagues (2011) report significant gains when using the *Mathematical Knowledge for Teaching (MKT) Measures* (Learning Mathematics for Teaching Project, 2008) for both teacher leaders and the teachers participating in the teacher leader workshops. Roesken-Winter and colleagues (2015) measure content knowledge and knowledge of math pedagogies and found positive gains with medium to large effect sizes. In addition to measurements of knowledge change, teachers' self-reports indicate that improvement in content knowledge boosts their confidence to engage in leadership activities (Hunziker, 2012; Kuzle & Biehler, 2015).
- *Growing leadership identity.* Seven of the studies report notable changes in teacher leaders' beliefs about leadership activities and their capacity to engage in those activities. These studies gathered data through self-reports from teacher leaders.

Findings to support future design of programs. Although the research studies do not link program attributes strongly to outcomes for teacher leaders, the researchers do devote significant space to analyzing the outcomes to make recommendations for the future design of programs. These lessons learned are organized into five categories: (1) challenges with content knowledge for teaching, (2) setting goals and staying focused, (3) creating productive communities for adult learners, (4) localizing the reform for diverse teachers and their needs, and (5) barriers to leadership identity and capacity.

- *Pressing colleagues' content knowledge and PCK.* Researchers mention numerous challenges that arise as teacher leaders learn to work with adult learners as opposed to students. Key among these issues is creating a culture among teacher participants where they feel safe to share their thinking and even their inadequacies in content or pedagogy. Establishing a safe environment is necessary for engaging teacher participants in "high press exchanges" and moving beyond polite sharing of ideas (Borko et al., 2014; Elliott et al., 2009; Jackson et al., 2015; Koellner et al., 2011). Teacher leaders did not initially know how to handle their colleagues' misconceptions and were uncomfortable with pointing out errors made by fellow teachers. Elliott and colleagues (2009) describe that teacher leaders struggled with using content tasks in professional development with teachers who exhibit a range of content knowledge. Teacher leaders also struggle with focusing their colleagues on student struggles with content and modifying content tasks to use with their students (Borko et al., 2014; Jackson et al., 2015; Koellner et al., 2011). Researchers suggest that teacher leaders need guidance on how to
    - develop thought-provoking questions around content-based tasks or classroom videos that are accessible to teachers with different degrees of content background (Borko et al., 2014; Elliott et al., 2009; Jackson et al., 2015) and
    - practice instructional moves to create rich discussions among teachers that move beyond "serial sharing of ideas" (Borko et al., 2014; Elliott et al., 2009; Jackson et al., 2015; Koballa et al., 2010).
- *Setting goals and staying focused.* One initial finding is that teacher leaders did not know how to set goals for their colleagues' short-term and long-term growth. Teacher leaders expressed uncertainty about what they could or should expect from their coworkers after the first workshop versus later in the program (Jackson et al., 2015). One suggestion from researchers is to assist teacher leaders as they

- develop short-term and long-term goals across the implementation of a reform program (Jackson et al., 2015) or for the mentoring process of a novice teacher (Koballa et al., 2010) and
  - use those goals to create a focus for each workshop or session. For example, they need guidance on how to articulate a purpose or goal for the inclusion of a content-based task or video clip (Borko et al., 2014; Elliott et al., 2009; Jackson et al., 2015). Teacher leaders share uncertainty about how to select the "right" clips or tasks, so practicing selecting the tasks and clips and articulating the purpose is an important activity for professional development.
- Even with clearly defined goals, teacher leaders struggle to stay focused and make decisions consistent with the program design, principles, and goals in "real time". While content tasks and video clips have potential for rich discussion, the direction of the discussions may be unpredictable. Teacher leaders benefit from
  - anticipating teacher ideas around a content task or classroom video, envisioning how the discussion will unfold (Elliott et al., 2009), and
  - the practice of instructional moves to stay focused when teacher participants veer off topic (Borko et al., 2014; Elliott et al., 2009; Koellner et al., 2011).
- *Localizing reforms for diverse teachers and their needs.* Teacher leaders are uniquely positioned to enact reform because of their extant knowledge of the context in which they work. A concern teacher leaders report is how to make reform curriculum or strategies relevant for their colleagues to ensure buy-in and minimize resistance from teachers. Researchers suggest teacher leaders
  - incorporate planning time, especially collaborative planning time with colleagues (Borko et al., 2014; Elliott et al., 2009; Jackson et al., 2015; Koellner et al., 2011; Yow & Lotter, 2016);
  - incorporate practice teaching time with students (Yow & Lotter, 2016; Lotter et al., 2014) or with fellow facilitators;
  - align goals of the workshops to teachers' personal goals or school goals (Koellner et al., 2011; Kuzle & Biehler, 2015); and
  - ground teachers' work in data from their classrooms.
- *Barriers to leadership identity and capacity.* Teacher leaders report limited views of leadership activities before their involvement with researchers (Hanuscin et al., 2012, 2014; Rebello et al., 2011; Yow, 2010; Yow & Lotter, 2016). Researchers find that building a professional community among teacher leaders provides them an avenue to seek and give help to one another (Hanuscin et al., 2014; Galosy & Gillespie, 2013). Teacher leaders need support as their identity shifts, sometimes from a position of isolation in their classroom to a position of an advocate beyond their classroom (Hanuscin et al., 2014; Larkin et al., 2010; Yow, 2010). Moving into the advocate position presents challenges to teacher leaders who believe they do not have the tenure to speak up (Yow, 2010) or lack support from their fellow colleagues and administrators. Larkin and colleagues (2009) depict a context in which support from administrators was constantly present and teacher agency was encouraged.

Conclusion

Current research studies on developing teacher leaders are one source of data to inform our research questions. While the body of literature remains smaller than we would like, the research studies that currently exist provide further evidence that current teacher leader development programs are finding success using diverse program designs and attributes. Across the sample of studies, researchers found an increase in teachers' (1) content knowledge, (2) pedagogical content knowledge and pedagogical skills, and (3) leadership identity. These findings resonate with the conclusions in Schiavo and colleagues (2010a) and Wenner and Campbell (2017) that development programs include activities for teacher leaders in these three areas, although how they structure and carry out the programs continues to vary widely. When looking at the attributes of teacher leader development programs in each of these areas additional patterns emerge:

1. Content knowledge
    a. How is it developed? Math programs tend to use carefully designed mathematical tasks that engage teacher leaders in problem solving, which leads to in-depth discussions about teachers' mathematical beliefs. In science programs, researchers use inquiry investigations to engage teachers in science practices. Both tasks and investigations serve to engage the teacher leader as a learner first, then are used to stimulate discussion about leading tasks/investigations with students or fellow teachers.
    b. How is effectiveness measured? Pretests and post-assessments measure content knowledge gains. Researchers used different instruments and did not provide reliability and validity in every case. One assessment, *Mathematical Knowledge for Teaching (MKT) Measures* (Learning Mathematics for Teaching Project, 2008), provides reliability and validity. The lack of consistent measurement in content knowledge prevents us from aggregating across studies.

2. Pedagogical knowledge and practices
    a. How is it developed? The mathematical tasks and inquiry investigations also serve as a starting point for looking closely at aspects of PCK. In addition to these, pedagogical inquiry, through analysis of classroom videos, examination of student work, or review of curriculum, further support expanding pedagogical knowledge and practice. In Hunziker (2012) pedagogical inquiry was supported through an action research project, which is likely typical in academic programs for teachers pursuing master's degrees.
    b. How is effectiveness measured? *Mathematical Knowledge for Teaching (MKT) Measures* was the only written assessment of PCK. Most studies measured effectiveness through observation protocols of the teacher leaders' practices (e.g., Constructivist Learning Environment Survey [CLES], Reform Teaching Observation Protocol [RTOP], or other researcher-constructed protocol). Self-reports of improvement in pedagogical practice is a common data source, which in turn is a common limitation to the research. Hunziker (2012), for example, had their sample unanimously agree that their pedagogical investigations were the single most beneficial development factor; yet, this finding comes from self-reports only, with no additional data confirming its importance.

3. Leadership identity and skills
    a. How is it developed? Strategies, skills, and activities to develop leadership identity and skills were the least well described of the three areas. Some researchers engage teachers in developing a leadership action plan and discussing leadership identity (e.g., Hanuscin et al.,

2012), while other programs support teachers in action research (e.g., Hunziker et al., 2012) or pedagogical investigations and various professional pursuits (e.g., Galosy & Gillespie, 2013).

b. How is effectiveness measured? One study used the Teacher Leadership Inventory (TLI), but the vast majority of research studies use self-report pre- and post-surveys regarding unspecified aspects of leadership and pre- and post-interviews with the interview protocol not provided.

In conclusion, we considered the research studies on Lukacs and Galluzzo's (2014) Models Two and Three. We did not observe striking differences in program attributes even though the goals for leadership were quite different between Models Two and Three. There was an emphasis on fidelity in many of the Model Two studies, whereas Model Three encouraged teachers in more diverse roles and pursuits. The preparation for those teacher leaders did not appear to be drastically different with respect to program structure, design principles, or even the strategies and skills that teacher leaders learned. Most researchers drew from high quality professional development design research to structure their programs, focusing a great deal on content development, collaboration, reflection, coherence and connection to school/district initiatives, and active learning activities for teacher leaders.

3. Math and Science Teacher Leadership Development Programs

The purpose of this section is to describe math/science teacher leadership programs with publicly available evidence of effectiveness and review program findings to identify attributes that support teacher leadership development. Multiple searches and individual recommendations yielded 70 programs, of which 15 met eligibility requirements (see methods section in Appendix A). The majority of programs did not meet eligibility criteria because they lacked publicly available evidence of effectiveness. We reviewed the publicly available program materials from programs that did meet eligibility and coded them for teacher leadership definitions/roles, goals, participants, program characteristics, leadership strategies, and findings. The review summarizes similarities and differences across programs and discusses findings from effectiveness studies.

Teacher Leadership Definitions and Roles

With few exceptions, programs defined teacher leadership in terms of the roles teacher leaders play in the particular program/project (see Table 3). Two programs—the Kenan Fellows Program for Teacher Leadership and the Knowles Science Teaching Foundation (KSTF) Teaching and Senior Fellows Program—offered broad visions of leadership in which teachers are catalysts of change who act in a variety of ways to bring about high quality instruction (Kenan) or educational improvement (KSTF). Other programs (e.g., Arizona Master Teachers of Mathematics) also described multiple roles for teachers but were more specific about what those roles involved. The most common roles for teacher leaders are facilitating professional development for colleagues (5 programs[2]), coaching/mentoring other teachers (5), facilitating local professional learning communities (4), and advocating for instructional reform (3). Other roles include serving as instructional expert/models (2), developing curriculum (2), influencing policy (2), presenting at conferences (1), providing resources to colleagues (1), and engaging the community in STEM education (1). These roles reflect many of those in the Teacher Leader Model Standards (Teacher Leader Exploratory Consortium, 2011) but lean most heavily on Domain IV: Facilitating Improvements in Instruction and Student Learning. That is not surprising given the discipline-specific nature of these programs. There is, however, variability in the other domains that programs emphasize when preparing/supporting teacher leaders to bring about instructional improvements.

[2] Numbers in parentheses refer to the number of research studies with that characteristic.

Mapping Lukacs and Galluzzo's (2014) descriptions onto program goals (see Table 3), the majority of programs (9) align with Model Two, preparing teachers for formal or informal positions that support math/science educational improvement in their schools (e.g., facilitating professional learning communities that develop/study inquiry-based teaching). As characterized in Model Two, teachers attend the programs because their school/district has a vision for math/science education (and formed a partnership to that end, typically with a university), but, most likely, they were not partners in creating or shaping the vision. As a result, part of leadership development involves bringing teachers into the vision and, perhaps, taking ownership, which relates to program fidelity discussed in Section 2.

Only two programs have strong resemblances to Model Three. These programs invest more heavily in supporting teachers themselves to create and facilitate improvement in their local contexts and beyond. For example, Kenan Fellows select STEM research internships and develop curriculum of their choosing to engage their students and the community in STEM education. KSTF Fellows have financial and staff support to develop and implement ideas for teachers, collectively improving education within their own context and beyond.

Program Goals

Programs goals range from one to five goals with a median of three goals. All programs share the broad goal of improving K-12 math and science learning for all students. Some programs emphasize particular improvements for students such as knowledge of math/science concepts (3), student enrollment in science courses (1), proficiency in science and engineering (1), preparation for STEM careers (1), inquiry experiences (1), or equity (1).

Several programs have broad goals such as strengthening the teaching profession (1), building the education system's capacity for continuous educational improvement (1), or improving teacher quality (1). Other programs' goals are more targeted toward specific aspects of teacher development, including enhancing teachers' content knowledge (4), pedagogical content knowledge (4), understanding of instructional technology (1), or awareness of national policy issues (1). Programs with goals that focus on instructional improvement include implementing research-based instruction (3), implementing national science or mathematics standards (2), or providing high quality curriculum (2).

A few programs' goals focus directly on teacher leadership knowledge and skills, such as building school-based leadership capacity (2), improving coaching knowledge (2), providing professional development (2), advocating for science education reforms (1), and strengthening professional interactions with colleagues (1). One program has a goal of becoming a national model for STEM teacher leadership development. In addition, four programs aim to build or strengthen partnerships to support improvement efforts.

As will be seen in the review of the programs themselves, goals reflect the approach programs take toward improvement and the outcomes they expect teacher leadership development to achieve. All represent an investment in teacher leadership but, as discussed earlier, approach teacher leadership in different ways.

Table 3: Program Definitions of Teacher Leadership

	Definitions of teacher leadership								Lukacs & Galluzzo	
Program	**Policy advocate**	**Coaching and/or mentoring**	**Facilitating professional learning community**	**Providing professional development**	**Curriculum development**	**Reform advocate**	**Drive improve-ment**	**Other**	**Model Two**	**Model Three**
Leadership in Freshman Physics						●			●	
Mathematics Education Collaborative		●						Model	●	
Science, Technology, and Engineering Leadership program (STELP)				●					●	
Science: It's Elementary				●		●			●	
Albert Einstein Distinguished Educator Fellowship (AEF) program	●								●	
Arizona Master Teachers of Mathematics		●	●	●	●	●		Presenting @ conferences	●	
Assessing Core Content and Ensuring Success in Science (ACCESS)			●						●	
Examining Mathematics Coaching (EMC)		●							●	
Exploratorium Teacher Institute leadership program		●							●	
Howard Hughes Science Grant Montgomery Public Schools				●					●	
Math Science Partnership of Southwest Pennsylvania			●	●					●	
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT)		●						Expert/ resource provider	●	
NebraskaMATH: Primarily Math			●						●	
Kenan Fellows Program for Teacher Leadership	●				●			Engaging community		●
Knowles Science Teaching Foundation Fellows programs							●			●

Program Characteristics

Information availability and/or program size affected how much data we had for program descriptions. In some cases, program descriptions were summaries, while others were much more detailed. For example, the Examining Mathematics Coaching program information included the daily agenda and activities for each day of its five-day coaching professional development summer program. In contrast, the Science, Technology, and Engineering Leadership Program information offered an overview of the program activities but not the details. Similarly, a five-year program like the Knowles Science Teaching Foundation's Teaching Fellowship or a comprehensive regional initiative like the Math Science Partnership of Southwest Pennsylvania did not provide the level of detail that the Science: It's Elementary program did about its three-day leadership conference. With that caveat, we tried to capture programs at the overview level and provide more detail when possible (see Table 4).

Four of the eligible programs are still operating and have been in existence for 16–22 years. The remaining programs existed for one or two grant cycles ranging from three to seven years with a mode of three years. Two programs are national in scope, one is a multi-state effort, eight are statewide or involve multiple regions/districts within a state, and four are regional or county-wide programs. The sizes of the programs vary accordingly and with longevity. Most programs (60%) have fewer than 100 total participants, and four programs have more than 300 total participants to date.

Most of the programs involve partnerships between universities and school districts. Eight programs have university leads, three are school districts, two have nonprofit status, one is a science museum, and one is a government agency. Eleven programs receive(d) some portion of their financial support through federal funding (eight from the National Science Foundation, two from the US Department of Education, and one from the Department of Energy), and one program had a state government grant. The Howard Hughes Medical Institute supported two programs, and the Knowles Science Teaching Foundation (a private operating foundation) supports its own Fellows programs. Eleven programs have/had a single funding source.

The duration of time participants spend in the program varies from three days to five years. However, the three-day summer program (Science: It's Elementary) is an anomaly. Almost 75% of programs last(ed) two years or longer. It should also be noted that in three programs—the Exploratorium, KSTF, and Kenan—teachers become lifelong participants after completing the initial program with optional further activity.

Table 4: Program Characteristics

Program title (model of teacher leadership)	Program staff	Partners	Years of program	Program lead	Program sponsor/ funder	Locale	Math, science, math & science, or STEM	Grade level	Duration	Total participants
Leadership in Freshman Physics (Model Two)	Math/science faculty at University of Missouri	20 school districts, University of Missouri	2009–2015	University	NSF MSP	Mid-west	Science	9th grade	3 years	80
Mathematics Education Collaborative (Model Two)	Mathematics education collaborative staff/ Regional math support team teachers	2 universities, 9 school districts in Washington State	2009–2014	University	US Department of Education MSP	Northwest	Math	K-12	2.5 years	53
Science, Technology, and Engineering Leadership Program (STELP) (Model Two)	Montgomery County Office of Curriculum and Instructional Programs staff	Montgomery County Public Schools	2009–2015(?)	School district	Howard Hughes Medical Institute	United States	STEM	K-12	2 years	47
Science: It's Elementary (Model Two)	ASSET, Inc. staff	Pennsylvania DOE, ASSET, Inc. a nonprofit; 78 Pennsylvania school districts	2010–2013	Nonprofit foundation	Pennsylvania Department of Education	Northeast	Science	K-8	3 days	30
Albert Einstein Distinguished Educator Fellowship (AEF) program (Model Two)	Government agency personnel	Department of Energy	2009–2014	Government agency	Department of Energy	United States	STEM	K-12	11 months	150+
Arizona Master Teachers of Mathematics (Model Two)	Arizona K-12 PD Center and Pima Regional Support Center	University of Arizona, 4 Arizona school districts	1994–present	University	NSF Noyce	Southwest	Math	K-8	4 years	20
Assessing Core Content and Ensuring Success in Science (ACCESS) (Model Two)	University faculty in science, science education	3 universities, 16 public schools in Catawba County School District, North Carolina	2010–2016	University	US Department of Education	United States	Science	K-8	3 years	30
Examining Mathematics Coaching (EMC) (Model Two)	Mathematics professors at Montana State and University of Idaho; Senior research associates from RMC Research Corporation	2 universities and 28 school districts across eight states (Colorado, Georgia, Idaho, Montana, Nebraska, North Dakota, Washington, and Wisconsin), RMC Research Corporation in Denver	2010–2013	University	NSF DRK-12	Northwest	Math	K-8	2 years	200

Program title (model of teacher leadership)	Program staff	Partners	Years of program	Program lead	Program sponsor/ funder	Locale	Math, science, math & science, or STEM	Grade level	Duration	Total participants
Exploratorium Teacher Institute leadership program (Model Two)	Exploratorium Teacher Institute staff	Exploratorium Science Museum	1998–present	Museum	Multiple funders including NSF	West coast	Math & science	Middle and high school	2 years	400
Howard Hughes Science Grant Montgomery Public Schools (Model Two)	Montgomery County Office of Curriculum and Instructional Programs staff	Elementary schools in the Montgomery County (MD)	2013–2016	School district	Howard Hughes Medical Institute	United States	Science	K-5	1 year	22
Math Science Partnership of Southwest Pennsylvania (Model Two)	Allegheny Intermediate Unit staff	Allegheny Intermediate Unit and 53 regional K-12 school districts	2006–2010	School district	NSF Math and Science Partnership	Northeast	Math & science	K-12	2 years	63
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT) (Model Two)	New Mexico State University mathematicians and educators	National Science Foundation, 1 university, 6 southern New Mexico school districts	2003–2010	University	NSF DRK-12	Southwest	Math	K-12	2 years	60
NebraskaMATH: Primarily Math (Model Two)	Math/math education faculty of University of Nebraska	1 university, 4 school districts in Nebraska	2012–2015	University	NSF DUE & multiple funders	Northwest	Math	K-3	2 years	300+
Kenan Fellows Program for Teacher Leadership (Model Three)	Partner university faculty/researchers, post-docs, museum researchers/staff, state/federal agency staff, industry scientists, and so forth	NC State University; Kenan Institute for Engineering, Technology, and Science; NC State Department of Public Instruction; area school districts; advisory board	2000–present	University	NSF DUE & multiple funders	East coast	STEM	K-12	1 year	350
Knowles Science Teaching Foundation Fellows Programs (Model Three)	KSTF staff, KSTF specialists	N/A	1999–present	Nonprofit foundation	Knowles Science Teaching Foundation	United States	Math & science	High school	5 years	300+

Approaches to Leadership Development

What participants learn about teacher leadership

Not surprisingly, all programs have a math/science focus as well as a leadership focus. There are a variety of things participants learn, and there are no distinct differences in content that distinguish Model Two from Model Three programs. Two-thirds of the programs emphasize reform-based instruction in some way (e.g., inquiry-based science teaching, worthwhile mathematical tasks) and 50% include math/science content instruction as part of their curriculum. Other math/science topics some programs include are assessment (3), how students learn (2), equitable teaching practices (2), national math or science standards (2), and cutting-edge scientific research (2) (see Table 5).

The leadership curriculum varies among programs as well. About half of the programs emphasize facilitation skills, especially for professional learning communities. A smaller number of programs include research on adult learners/learning (4) and/or characteristics of effective professional development (3). Four programs indicate addressing general aspects of teacher leadership (e.g., formal/informal leadership roles, barriers, and sustainability). A few programs specifically develop mentoring/coaching knowledge and skills, presentation skills, and/or address change processes (3). Other leadership development topics include education issues/policies (2), systems thinking (2), community engagement (1), collaboration norms/skills (1), working with data/artifacts of practice (1), and/or teacher inquiry (1). Eleven programs address one or two aspects of leadership, while the remaining four programs address multiple dimensions (see Table 5).

Most programs (80%) integrate math/science learning with leadership development throughout the program. Three programs treat leadership development separately from math/science learning. MEC uses a "delayed leadership model" which immerses teachers in math/science content and instruction first and then addresses leadership. ACCESS has a similar approach that heavily emphasizes content understanding and inquiry-based teaching in its summer institutes, followed by a teacher leadership professional learning community during the academic year. EMC offers participants two separate five-day summer residential modules: one in mathematics and one in coaching. Their research design varies which module the participants receive first so they can compare the effects.

How participants learn about teacher leadership

At its core, teacher leadership development is professional development. A recent report from the National Academies of Sciences, Engineering, and Medicine (2015) described a consensus model of effective professional development derived from over a decade of research. The characteristics are as follows:

- *content focus—learning opportunities for teachers that focus on subject matter content and how students learn that content;*
- *sufficient duration—both the total number of hours and the span of time over which the hours take place;*
- *active learning—can take a number of forms, including observing expert teachers, followed by interactive feedback and discussion, reviewing student work, or leading discussions;*
- *coherence—consistency with other learning experiences and with school, district, and state policy; and*
- *collective participation—participation of teachers from the same school, grade, or department* (p. 118).

In general, the programs reviewed adhered to these features of effective professional development programs. All, of course, (given the selection criterion) have a math and/or science focus, and, as indicated above, most extend over a span of time (although the number of contact hours was often not available).

Active learning, as opposed to passively sitting and listening, includes interactive feedback and discussion, presentations, work with data, lesson or task design, role-play, or practicums (Desimone, 2009). Although about 50% of programs use structures that are sometimes associated with passive learning such as courses, institutes or academies (8), they all actively involve teachers in learning. For example, Leadership in Freshman Physics summer academies set aside time for teachers to discuss various formal and informal avenues of teacher leadership, develop a leadership action plan (a strategy most programs use), and share challenges and growth over time. Four programs include practicums, apprenticeships, or internships as part of the leadership development experience. Other popular strategies for teacher leadership development include coaching, mentoring, observations (live or video), and modeling or co-leading professional development/professional learning communities. Active learning strategies less frequently mentioned are role-play, blogging, designing curriculum, planning professional development sessions, and presentations (see Table 6).

Program coherence generally involved professional development support during implementation into practice. Two-thirds of programs offered support for implementing teacher leadership such as facilitating teacher community (5), coaching and/or mentoring (4), or additional workshops (3). Several programs relied on online interactions to support taking learning into practice, including webinars or discussion groups (see Table 6).

Finally, in terms of collective participation, some of the state, regional, or district programs (Math Science Partnership, Nebraska Math, and the Montgomery Public Schools programs) brought together teachers in the same subject matter from a school or district to jointly participate in the program. Five programs used cohort models, often supported by online tools, as an alternative collective participation strategy to build ongoing communities even though the teachers were not in the same school/district.

A handful of programs extended collective participation beyond the program participants themselves. In these programs, teacher leadership development included having participants learn how to strengthen teacher collaboration in their local contexts. Participants (generally using a cohort model) develop as a professional learning community themselves within the program and, in the process, learn how to strengthen teacher collaboration in their own contexts. For instance, in the Examining Mathematics Coaching and the Knowles Science Teaching Foundation Fellows programs, participants establish group norms and use protocols to guide discussions. Arizona Master Teachers of Mathematics, Accessing Core Content and Ensuring Success in Science, and Leadership in Freshman Physics all use professional learning communities within the program as a way for teachers to learn how to support professional learning communities in their districts/schools. The Knowles Science Teaching Foundation grounds leadership development in collective teacher inquiry—Fellows work together to generate knowledge by studying their practice and teaching contexts and, in the process, develop skills and access resources that can support collective inquiry elsewhere.

In summary, although programs generally incorporated characteristics of effective professional development, they each put together a different mix of content and strategies to produce their intended teacher leadership outcomes. Again, there were no differences that clearly distinguished Model Two from Model Three programs. The next section discusses how effective these approaches proved to be for supporting math/science teacher leadership development.

Table 5: What Program Participants Learn

		Leadership content/pedagogy														Disciplinary content/pedagogy							
	Program title	Formal / informal leadership roles, barriers, sustainability	Adult learners / learning	Community engagement	Change process	Education issues / policies	Mentoring knowledge / skills	Systems thinking	Teacher inquiry dispositions / practices	How to work with data / artifacts	Coaching knowledge / models / skills	Characteristics of effective PD	Collaboration norms / skills	Facilitation skills	Presentation skills	National standards	Cutting-edge research	Content understanding	Content knowledge for teaching	Reform-based / effective instruction	Equitable teaching practices	How students learn	Student assessment
Model Two	Leadership in Freshman Physics	●															●	●		●			●
Model Two	Mathematics Education Collaborative													●									
Model Two	Science, Technology, and Engineering Leadership Program (STELP)											●		●		●		●		●			
Model Two	Science: It's Elementary	●																●		●			●
Model Two	Albert Einstein Distinguished Educator Fellowship (AEF) program					●																	
Model Two	Arizona Master Teachers of Mathematics						●	●			●				●						●	●	
Model Two	Assessing Core Content and Ensuring Success in Science (ACCESS)													●				●		●			
Model Two	Examining Mathematics Coaching (EMC)		●		●		●				●	●						●		●		●	
Model Two	Exploratorium Teacher Institute leadership program						●				●									●			
Model Two	Howard Hughes Science Grant Montgomery Public Schools		●													●							●
Model Two	Math Science Partnership of Southwest Pennsylvania				●									●				●		●			
Model Two	Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT)		●											●				●		●			
Model Two	NebraskaMATH: Primarily Math											●		●				●		●			
Model Three	Kenan Fellows Program for Teacher Leadership	●	●	●		●									●		●						
Model Three	Knowles Science Teaching Foundation Fellows programs	●			●			●	●	●			●	●	●				●	●	●		

Table 6: How Program Participants Learn

	Structures									Strategies																		Tools and resources
Program title (model of teacher leadership)	**Course / courses**	**Institutes / academies**	**Practicum apprenticeship**	**Internship**	**Workshops**	**Cohort**	**Online community**	**Study group / PLC**	**Webinars**	**Analyze student work / data**	**Study research**	**Interview students**	**Design student tasks**	**Develop PD plan for others**	**Present what they learn**	**Develop personal PD or leadership goals / plans**	**Modeling / experiencing instruction**	**Coaching**	**Mentoring**	**Classroom observation / video**	**Coaching PD videos or observations**	**Role-play**	**Co-lead PD**	**Blogging**	**Setting norms**	**Collective inquiry into practice**	**Follow-up reflection / learning sessions**	**Protocols**
Leadership in Freshman Physics (Model Two)	●						●	●								●	●	●	●					●				
Mathematics Education Collaborative (Model Two)			●		●		●		●											●								
Science, Technology, and Engineering Leadership Program (STELP) (Model Two)					●			●										●										
Science: It's Elementary (Model Two)											●					●	●				●	●	●					
Albert Einstein Distinguished Educator Fellowship (AEF) program (Model Two)						●													●									
Arizona Master Teachers of Mathematics (Model Two)		●	●			●		●		●	●	●	●		●	●												
Assessing Core Content and Ensuring Success in Science (ACCESS) (Model Two)		●			●			●									●	●										
Examining Mathematics Coaching (EMC) (Model Two)	●										●									●	●	●			●			●
Exploratorium Teacher Institute leadership program (Model Two)			●				●												●								●	
Howard Hughes Science Grant Montgomery Public Schools (Model Two)					●									●			●											
Math Science Partnership of Southwest Pennsylvania (Model Two)		●								●							●	●									●	
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT) (Model Two)	●	●				●										●		●		●							●	
NebraskaMATH: Primarily Math (Model Two)	●													●		●												
Kenan Fellows Program for Teacher Leadership (Model Three)		●		●		●	●									●		●	●	●				●				
Knowles Science Teaching Foundation Fellows programs (Model Three)					●	●	●			●					●	●		●						●	●	●		●

Findings

Each of the programs made some evidence of impact publicly available, although the evidence varied in form, quality, and quantity (see Appendix A). Although it is difficult to attribute outcomes to a particular program that exists in a sea of other influences, programs reported effects across a range of outcomes on the participants and beyond the participants (e.g., students or colleagues). Unfortunately, as in the research review, many of the program evaluation studies included here did not examine the links between specific program attributes and outcomes. However, some studies did tease out specific characteristics that influenced program outcomes and might inform future program design.

Findings that show evidence of effectiveness for participants. Twelve programs reported significant positive gains or changes in disciplinary content knowledge/pedagogy, leadership attitudes and skills, and/or leadership activity of participants (see Table 7).

- *Disciplinary content knowledge/pedagogy and practices.* One program reported positive gains in teacher content knowledge. Five programs reported increased knowledge and skills for teaching math and science, which included improved understanding of student misconceptions (1), the Next Generation Science Standards (2), and/or reform-based mathematics/science teaching (2). Three programs saw greater implementation of reform-based math and/or science teaching practices by their program participants.

- *Leadership knowledge and skills.* Eight programs described one or more effects on participants' preparation to exercise leadership. These effects are quite varied and tend to be program-specific with little overlap. Two programs documented increased knowledge and skills assuming formal leadership roles, two programs reported improved mentoring/coaching skills, and two programs found participants had greater confidence in their leadership capabilities. Additional effects reported by single programs were expanded views of teacher leadership, stronger teacher leadership identity, increased knowledge of educational policy, improved understanding/capacity to work with adult learners, greater knowledge/skills for public speaking, and increased interest and ability to network with colleagues.

- *Leadership activity.* Five programs detected effects on participants' leadership activity. For example, Kenan Fellows reported taking on more leadership roles beyond their own classroom compared with their colleagues (although 50% never return to the classroom). KSTF Fellows assumed leadership roles in their schools earlier in their careers and more often than comparable teachers.

Findings that show evidence of effectiveness beyond participants. While increased leadership preparation or activity offers evidence that programs are supporting teacher leadership development, the larger issue is what impact the leadership developed within these programs has on math/science teachers, students, classrooms, or schools. This "so what" question is even more difficult to answer (and attribute to a program) than effects on participants. Yet, six programs offer some evidence (again, varied in type and quantity) of effects on other teachers' practice, student attitudes/performance, and/or school cultures (see Table 7).

- *Other teachers' practices.* Two programs reported improvements in reform-based teaching practices by teachers whom program participants coached.

- *Students.* One program found that a greater proportion of students met standards in teacher leader participants' classrooms than the students in a comparison group. Another program reported increased student ability in, and beliefs about, mathematics.

- *School culture.* One program reported an increased likelihood that other teachers would seek advice from the teacher leader who participated in the program, and three programs found an increase in

teacher collaboration around math/science teaching and learning. Findings about strengthening the professional teacher community seem particularly important for math/science educational improvement given the growing body of evidence that strong professional connections between teachers (teacher social capital) are associated with higher levels of student performance (Pil & Leana, 2009; Moolenar et al., 2012). Attention to social networks is becoming more prevalent in research and evaluation of school leadership and teacher professional development (Coburn & Russell, 2008; Baker-Doyle & Yoon, 2011; Finnigan, Daly, & Che, 2013). One of the program evaluations—Primarily Math (Nebraska Math)—included an analysis of teachers' mathematical advice networks in participants' schools. The analysis showed denser teacher advice networks after program participation and program participants occupied more central roles within the networks.

Findings to support future design of programs. Eight programs (over 50%) reported program effects but did not link them to specific program attributes. Since programs involved a mix of content and strategies for teacher leadership development, it is not possible to tell which program characteristics were most effective for achieving particular outcomes. While the remaining seven programs did find specific program attributes that contributed to program effectiveness, the evidence leans heavily on participant self-report and there is again a wide variety of findings. The idiosyncratic nature of the findings makes it difficult to draw any firm conclusions about attributes of effective programs. However, program findings about the following attributes may be helpful in designing future programs (see Table 7).

- *Cohort model.* Four programs found a cohort model that groups teachers together as they enter the program, provides common learning experiences, and keeps them together over the duration of the program (2) or their career (2) is effective for teacher leadership development. However, three programs also found that common experiences for the cohort need to be balanced by an individualized learning plan for participants so their leadership development is relevant to their own situation/context.

- *Professional learning communities.* Five programs found professional learning communities effective for facilitating participant learning and leadership. Opportunities for teachers to build and experience professional learning communities within the program supported teachers facilitating teacher collaboration in their own contexts (2) and helped sustain their leadership efforts over time.

- *Practice-based learning.* Three programs found that opportunities to connect learning about math/science or leadership with participants' own practice and context was important for effective teacher leadership development.

- *Inquiry and reflection.* Two programs had evidence that opportunities for teacher inquiry and reflection helped build participants' capacity to support improvement for themselves and with others.

- *Content knowledge and PCK.* Two programs found that time for participants to deepen their content understanding and pedagogical knowledge was an important part of math/science teacher leadership development.

- *Adult learning.* One program found that support for understanding adult learners was a key piece for learning to effectively facilitate professional development.

- *Change process.* One program had evidence that building awareness of the change process within the program supported teacher leadership development.

- *Feedback.* One program found that regular participant feedback and explicit, timely action as needed from staff supported participant learning.

In addition to these program attributes, a few programs had some evidence that particular resources supported program effectiveness and/or sustainability. The Exploratorium Teacher Institute found that hiring program staff with teacher leadership experience and having the resources necessary to select, train, and support program staff as well as participants was necessary for their program's success. The Arizona Master Teachers of Mathematics program found their staffing model that included university faculty, veteran math teachers, and teacher leadership development specialists provided the complementary expertise they needed to be effective. Two programs offered explicit advice about participant selection: Arizona Master Teachers of Mathematics' selection of teachers who are highly motivated and experienced proved worthwhile, and The Math Science Partnership of Southwest Pennsylvania had greater effects when they had a critical mass of teacher leaders within a region.

Findings about negative or unintended effects. Four programs reported effects that were negative or unintended that may also be informative to future program design (see Table 7). One program did not have the impact they hoped for because participants' content understanding needed more time to develop. Two other programs also had disappointing results. In one program, participants did not share program resources with their colleagues as expected and teacher collaboration did not increase in two-thirds of participants' schools. In the other program, challenging school contexts and competing reform demands limited the program's impact. Finally, while the Albert Einstein Distinguished Educator Fellowship program had positive impacts on participants' teacher leadership development, 50 percent of them did not return to classroom teaching, which was not an outcome the program intended.

Table 7: Program Findings

	Effects on participants			Effects beyond participants		Effects of program characteristics			
Program title (model of teacher leadership)	**Leadership activity**	**Leadership preparedness**	**Disciplinary content / pedagogy**	**Effects on classrooms & students**	**Effects within schools**	**Design**	**Tools / resources**	**Participants**	**Negative effects or unintended consequences**
Leadership in Freshman Physics (Model Two)	•	•							
Mathematics Education Collaborative (Model Two)			•	•					
Science, Technology, and Engineering Leadership Program (STELP) (Model Two)			•						Limited sharing of program resources with other teachers; only 1/3 reported increased teacher collaboration in their schools
Science: It's Elementary (Model Two)						•			Many of the program participants have tenuous understanding of the science content they are expected to teach
Albert Einstein Distinguished Educator Fellowship (AEF) program (Model Two)	•	•							50% do not return to classroom
Arizona Master Teachers of Mathematics (Model Two)					•	•	•	•	
Assessing Core Content and Ensuring Success in Science (ACCESS) (Model Two)		•	•		•				
Examining Mathematics Coaching (EMC) (Model Two)		•		•					Teachers' context and competing demands negatively impacted program effects

	Effects on participants			Effects beyond participants		Effects of program characteristics			Negative effects or unintended consequences
Program title (model of teacher leadership)	**Leadership activity**	**Leadership preparedness**	**Disciplinary content / pedagogy**	**Effects on classrooms & students**	**Effects within schools**	**Design**	**Tools / resources**	**Participants**	
Exploratorium Teacher Institute leadership program (Model Two)		●				●	●		
Howard Hughes Science Grant Montgomery Public Schools (Model Two)		●	●			●			
Math Science Partnership of Southwest Pennsylvania (Model Two)		●	●			●		●	
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT) (Model Two)						●			
NebraskaMATH: Primarily Math (Model Two	●		●	●	●				
Kenan Fellows Program for Teacher Leadership (Model Three)	●	●			●				
Knowles Science Teaching Foundation Fellows programs (Model Three)	●		●	●	●	●			

Conclusion

As noted earlier, the program attributes that are effective for developing math/science teacher leadership mimic those found for teacher professional development in general: sustained over time, context-specific, grounded in practice, and active, collective learning. Math or science teaching and learning clearly matter for teacher leadership development when teachers are expected to be formal or informal instructional leaders (e.g., informal advice givers, coaches, or mentors). However, what emerged from teacher leadership effects was not specific to math or science but related more broadly to teacher leadership development in general.

To some extent, this review extends Schiavo, Miller, Busey, and King's (2010a) summary of empirical research on experiences and interventions to develop teacher leadership. Aspects of the content, design, and delivery of programs that we analyzed are similar to those that Schiavo and colleagues identified as effective. Specifically, they found that programs improved teacher leaders' disciplinary knowledge, knowledge of instruction, and knowledge of leadership. We see similar patterns in the program descriptions and, in some cases, the findings in our program review.

1. Content knowledge
    a. How is it developed? Eight of 15 programs included some math/science content learning as part of participants' leadership development. Program descriptions, in most cases, indicated that participants learned content in the ways they were expected to teach the content to their students (e.g., inquiry-based science learning activities).
    b. How is effectiveness measured? Four programs reported measuring content knowledge gains and did so using pre-assessment and post-assessment of teacher content knowledge. Two programs used assessment provided by an external evaluator (no additional information available). One program used the *Mathematical Knowledge for Teaching (MKT) Measures* instrument, which reports validity and reliability (Learning Mathematics for Teaching Project, 2008). Another used the Test of Understanding Graphs in Kinematics (TUG-K) and Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART).
2. Pedagogical knowledge and practices
    a. How is it developed? Participants generally learned how to teach mathematics or science within the program by experiencing the kind of instruction they were expected to use with students, facilitated by program staff. Some programs also included learning about national standards, analyzing student work or classroom video, designing student tasks, interviewing students, or collectively studying their practice (teacher inquiry). A few programs included classroom coaching or mentoring of participants by program staff.
    b. How is effectiveness measured? The 10 programs that included a focus on pedagogical knowledge and practices in their teacher leadership development primarily measured effectiveness with participant survey data about improved confidence in teaching math/science and their classroom practices. One program used the *Mathematical Knowledge for Teaching (MKT) Measures* instrument as a pre/post assessment of teachers' instructional practices, and another used the Test of Understanding Graphs in Kinematics (TUG-K) and Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART). Two programs used the Reform Teaching Observation Protocol (RTOP) to measure teaching effectiveness. One program administered the Science Teaching Efficacy Beliefs instrument to measure changes in teachers' attitudes and beliefs. Two programs included student achievement data as one of their measures of pedagogical effectiveness. One program

had participants' coaches/mentors report on the teaching effectiveness, and one program included a survey of participants' school leaders as a measure of teaching effectiveness. The majority of programs used comparison groups or pre/post designs to assess pedagogical improvement.

3. Leadership identity and skills

   a. How is it developed? There is a wide array of approaches to leadership development across programs, and each program used its own mix of strategies and activities. Several programs provided mentors or coaches to guide participants as they engaged in teacher leadership in their schools or in practicums/apprenticeships elsewhere. Some programs had participants form professional learning communities as a way of learning how to build those kinds of communities in their local contexts. One program had participants view coaching videos, while another had them observe and then co-lead professional development sessions with program staff. A few programs had participants develop personal professional development or leadership action plans or professional development plans for others. Other approaches included role-play, blogging, and teacher inquiry. Each program also had its own unique mix of what teachers learned about leadership. Some of the topics included were traits of an effective leader, coaching models, systems change, adult learners, facilitation skills, effective collaboration, and community engagement.

   b. How is effectiveness measured? Most programs used some form of participant self-report to measure leadership development effectiveness. These included surveys about leadership activities, leadership knowledge and skills, and/or confidence in taking on leadership roles. Programs (or their external evaluators) tended to design or adapt their own instruments. One program reported adapting their teacher leadership survey from one developed by Dozier and Barnes (2003). A few programs analyzed participants' written reflections to assess their leadership development. Several programs collected data about participants' leadership activity or effectiveness from their supervisors, coaches/mentors, or colleagues. One program included case studies as examples of effective teacher leadership. Another program assessed effectiveness using social network methods to see if the teacher leader influenced the structure of teacher advice networks in her or his school and where the teacher leader was positioned in the network.

4. Discussion

While the research studies and programs included here may not be representative of all math/science teacher leadership programs, our reviews found limited evidence available to support strong claims about attributes of effective math/science teacher leadership development programs. These data suggest that Lukacs and Galluzzo's (2014) Model Two is the predominant approach to math/science teacher leadership development and reflects Schiavo and colleagues' (2010b) finding that studies tend to describe teacher leadership practices in terms of implementation of instructional materials, providing resources, leading workshops, and working alongside teachers in their classrooms to enact reforms, which they typically did not design. Additionally, programs characterized as Model Three supported teachers in initiating and facilitating changes that they envisioned beyond their classrooms. However, there is much more to learn about differences in teacher leadership development within and between models and their respective contributions to educational improvement.

One problem is a lack of studies that link attributes to outcomes, which makes it difficult to discern which approaches to leadership development are more beneficial than others. Another problem is that the programs and studies reviewed are so different from each other that meaningful comparisons are difficult to draw. The similarities that do occur tend to be in the areas of math/science content and pedagogical professional development. There appears to be little consensus around designing teacher leadership development beyond broad categories for content development and leadership development. Programs vary in their approaches to leadership development (i.e., structure, duration, activities) and do not use common instruments to measure effectiveness or make comparisons. There is one finding here and another finding there and little in common to pull together attributes of effective programs. As a result, the attributes identified in the discussions above should be regarded as promising or features to study in future research rather than hard and fast rules for designing or implementing math/science teacher leadership development programs.

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6. Supplemental Resources

Research Review Methods

There were three steps in the research literature review process: the literature search, eligibility screening, and full review and coding for eligible research studies. Each of these steps is described in more detail below.

Search

The literature search used Google Scholar, Web of Science, ERIC, and university-based search catalogs. Two researchers divided the searches using an agreed-upon set of keywords, for example, “teacher leadership AND math OR science OR STEM”. This process yielded 76 potential abstracts. A third researcher reviewed references in eight well-matched empirical studies. Reviewing the references proved to be a productive source of empirical studies that were not identified in database searches. This process yielded another nine potential studies. The keyword search was expanded to include variations of “coach”, “mentor”, and “facilitator”. Together the search process yielded a total of 89 potential empirical studies.

Eligibility Screening

In general, the searches yielded a variety of scholarly papers, from empirical studies to evaluation reports to theoretical descriptions of teacher leadership. We collected abstracts from all 89 articles and used predetermined criteria to screen for eligibility. The eligibility criteria included the following:

- Written in English
- In a peer-reviewed publication
- About K-12 education
- Focused on math and science education, or STEM
- Focused on teacher leader development or preparation
- Addresses an explicit research question
- Includes a defined data set with articulated data analysis procedures

We used a form to document whether each program was eligible or not eligible and, when ineligible, which criterion was not satisfied. From reading the abstracts alone, 44 studies were eliminated from the review process after the initial screening. The most common criteria not met included (1) in a peer-reviewed publication, (2) defined data set with articulated data analysis procedure, and (3) focused on math and science education.

We then retrieved the full articles for the remaining 45 studies and rescreened the studies based on the set criteria. Eighteen studies met all the criteria (i.e., 20.2% of the original 89 studies). The other 27 studies were removed. Table A1 shows the most common criteria that were not satisfied across the original 89 articles. Table A2 shows the criteria not met for the 27 studies that passed original screening of abstracts but were subsequently removed after examining the full manuscript.

Full Review

The full review process involved coding each article based on the researcher's definition of teacher leadership, program attributes, research methodology (e.g., research goals, participants, data collection, data analysis), and research findings. We used a form to enter information from the research article. Based on the program description and program attributes, we coded the research study in terms of (1) source of the reform (i.e., internal or external to teacher leader) and (2) degree of agency in the reform. We then determined if the program aligns most closely with Model Two or Model Three of Lukacs and Galluzzo's (2014) framework.

Table A1: Studies Not Meeting Specific Eligibility Criteria

Eligibility criteria	Studies not meeting eligibility*
The research study is published in English and accessible for review	0
The research study takes place within K-12 education	6 (6.74%)
The research study addresses an explicit question or topic	6 (6.74%)
The research study focuses on math, science, or STEM education	13 (14.61%)
The research study includes a defined and bounded data set and procedures for data analysis	18 (20.22%)
The research study is peer reviewed	29 (32.58%)
The research study focuses on teacher leadership preparation, learning, or development	42 (47.19%)

*Does not add to 100% because some studies did not meet multiple eligibility criteria.

Table A2: List of Studies Passing Initial Screening But Not Satisfying Eligibility Criteria

	Eligibility criteria						
Research studies excluded from review	**English / accessible**	**Peer reviewed**	**K-12**	**Math/science STEM**	**Development**	**Question or topic**	**Empirical**
Banilower, E. R., Fulp, S. L., & Warren, C. L. (2008). *Science: It's Elementary. Year Two Evaluation Report.* Horizon Research, Inc. (NJ1) AND Banilower, E. R., Fulp, S. L., & Warren, C. L. (2010). *Science: It's Elementary. Year Four Evaluation Report.* Horizon Research, Inc. (NJ1).	Yes	NO	Yes	Yes	NO	Yes	Yes
Bradbury, L.U. (2010). Educative mentoring: Promoting reform-based science teaching through mentoring relationships. *Science Education, 94*(6), 1049-1071.	Yes	Yes	Yes	Yes	Yes	NO	NO
Bunt, N. R., Martin, D. R. A., Lease, B. B., Rice, K. M., & Rose, G. K. (2011). *Perspectives on Deepening Teachers' Science Content Knowledge: The Case of the Southwest Pennsylvania Math Science Partnership.*	Yes	NO	Yes	Yes	Yes	Yes	NO
Felton, P. (2014). Preparing teacher leaders. *Teaching Children Mathematics, 21*(2), 92-99.	Yes	Yes	Yes	Yes	Yes	NO	NO
Finchum, T. R. (2014). Becoming a Leader: Finding My Voice. *Teaching Children Mathematics, 21*(2), 100-106.	Yes	Yes	Yes	Yes	Yes	NO	NO
Fulp, S. L., Warren, C. L., & Banilower, E. R. (2009). *Science: It's Elementary. Year Three Evaluation Report.* Horizon Research, Inc. (NJ1).	Yes	NO	Yes	Yes	NO	Yes	Yes
Glazerman, S., & Seifullah, A. (2012). *An Evaluation of the Chicago Teacher Advancement Program (Chicago TAP) after Four Years. Final Report*. Mathematica Policy Research, Inc.	Yes	Yes	Yes	NO	NO	Yes	Yes
Harmon, H. L., & Smith, K. C. (2012). *Legacy of the Rural Systemic Initiatives: Innovation, Leadership, Teacher Development, and Lessons Learned.* Edvantia (NJ1).	Yes	NO	Yes	Yes	NO	Yes	Yes
Kent, A. M., Green, A. M., & Feldman, P. (2012). Fostering the success of new teachers: Developing lead teachers in a statewide teacher mentoring program. *Current Issues in Education, 15*(3).	Yes	Yes	Yes	NO	Yes	Yes	Yes
Kinzer, C. J., Rincón, M., Ward, J., Rincón, R., & Gomez, L. (2014). Teacher Leaders Advancing Mathematics Learning. *Teaching Children Mathematics, 20*(6), 384-391.	Yes	Yes	Yes	Yes	Yes	Yes	NO
Lewis, J. (2016). Learning to lead, leading to learn: How facilitators learn to lead lesson study. *ZDM, 48(4), 527-540*.	Yes	Yes	Yes	Yes	NO	Yes	Yes
Lu, Y. J., & Chung, J. (2010). Essentials of Developing a Mathematics Teacher Leader Project. In *Proceedings of the 34th Conference of the International Group for the Psychology of Mathematics Education, 3*, 233-240.	Yes	NO	Yes	Yes	Yes	Yes	Yes
Merrill, C., & Daugherty, J. (2010). *STEM education and leadership: A mathematics and science partnership approach.* Retrieved from http://eric.ed.gov/?id=EJ914280	Yes	Yes	Yes	Yes	Yes	Yes	NO
National Institute for Excellence in Teaching. (2014). *Developing teacher leadership in Iowa: Saydel and Central Decatur Schools.*	Yes	Yes	Yes	NO	Yes	NO	NO

	Eligibility criteria						
Research studies excluded from review	**English / accessible**	**Peer reviewed**	**K-12**	**Math/science STEM**	**Development**	**Question or topic**	**Empirical**
Nazareno, L. (2014). Teachers Lead the Way in Denver: A School Born through Collaboration Attracted Accomplished Teachers, Exemplifies Leadership by Teachers, and Sets an Example for Students. *Phi Delta Kappan, 95*(7), 24.	Yes	Yes	Yes	NO	NO	NO	NO
Neumerski, C. M. (2013). Rethinking Instructional Leadership, a Review What Do We Know About Principal, Teacher, and Coach Instructional Leadership, and Where Should We Go from Here? *Educational administration quarterly, 49*(2), 310-347.	Yes	Yes	Yes	NO	Yes	NO	NO
Sinha, S., Hanuscin, D. L., Rebello, C. M., Muslu, N., & Cheng, Y. W. (2012). Confronting myths about teacher leadership. *European Journal of Physics Education, 3*(2), 12.	Yes	Yes	Yes	Yes	Yes	Yes	NO
Slavit, D., Nelson, T. H., & Kennedy, A. (2010). Laser Focus on Content Strengthens Teacher Teams. *Journal of staff development, 31*(5), 18.	Yes	Yes	Yes	Yes	NO	NO	NO
Eddy Spicer, D. H. (2010). Power and knowledge-building in teacher inquiry: Negotiating interpersonal and ideational difference. *Language and Education, 25*(1), 1-17.	Yes	Yes	Yes	Yes	NO	Yes	Yes
Thomasian, J. (2011). *Building a Science, Technology, Engineering, and Math Education Agenda: An Update of State Actions.* NGA Center for Best Practices. Retrieved from http://eric.ed.gov/?id=ED532528	Yes	NO	Yes	Yes	NO	Yes	NO
van Es, E. A., Tunney, J., Goldsmith, L. T., & Seago, N. (2014). A framework for the facilitation of teachers' analysis of video. *Journal of Teacher Education, 65*(4), 340-356.	Yes	Yes	Yes	Yes	NO*	Yes	Yes
White, D., & Yow, J. (February 2015). *Math Teachers' Circles: Connections to teacher leadership.* Paper presented at the Research in Undergraduate Mathematic Education.	Yes	NO	Yes	Yes	Yes	Yes	Yes
Wolanin, N., & Wade, J. (2015). *Evaluation of the Howard Hughes Science Grant Project, Year One.* Montgomery County Public Schools.	Yes	NO	Yes	Yes	NO	Yes	Yes
Wolanin, N. L., & Wade, J. H. (2013). *Evaluation of the Science, Technology, and Engineering Leadership Program, Year Two.* Montgomery County Public Schools.	Yes	NO	Yes	Yes	NO	Yes	Yes
Wolffe, R., Crowe, H. A., Evens, W., & McConnaughay, K. (2013). Portfolio as a Teaching Method: A Capstone Project to Promote Recognition of Professional Growth. *Journal of College Teaching & Learning (Online), 10*(1), 1.	Yes	Yes	Yes	Yes	NO	Yes	Yes
Yager, S. O., Akcay, H., Dogan, O. K., & Yager, R. E. (2013). Student Views of Teacher Actions in Science Classrooms Designed to Meet Current Reforms. *Journal of Science Education and Technology, 22*(6), 974-983.	Yes	Yes	Yes	Yes	NO	Yes	Yes
Yow, J. (2013). Leadership from Within Secondary Mathematics Classrooms: Vignettes Along a Teacher-Leader Continuum. *Journal of Mathematics Education at Teachers College, 4*, 61-66	*Redundant with Yow (2010) included in eligible sample*						

Program Review Methods

There were three steps in the program review process: program search, eligibility review, and full review for eligible programs. Each of these steps is described in more detail below.

Search

The program search process included electronic searches and recommendations from individuals knowledgeable about teacher leadership programs. The four searches were conducted on Google (advanced search; keywords: Math OR Science OR STEM teacher leadership); Robert Noyce Teacher Scholarship program (advanced search; keywords: Master Teaching Fellows); The National Science Foundation EHR search engine (advanced search; keywords: teacher leader in abstract or title, active projects), and the Department of Education Math Science Partnership program search engine (advanced search; keywords: leader and filtered for projects that met criteria for rigorous evaluations). Additional recommendations were solicited from project staff, advisory board members, the Research on Teacher Leadership section of the American Educational Research Association, members of the National Association for Research on Science Teaching, and members of the National Council of Teachers of Mathematics. The searches and recommendations yielded 70 programs (50 from internet searches; 20 from recommendations), which were then screened for eligibility (see Table A3).

Eligibility Screening

We followed search links and conducted additional electronic searches for program materials (websites, evaluation reports, published articles, media reports) for the 70 programs for eligibility screening. We used the materials to respond to the predetermined eligibility criteria:

- specific to math and/or science teachers
- focused on teacher leadership preparation, learning, development, support
- extends beyond local level—not just school specific
- K-12 education
- systemic approach (connection with context in which leadership will be enacted)
- descriptions of program goals, strategies, and outcomes
- evidence of effectiveness

We used a form to collect the responses and document whether each program was eligible or not eligible.

Fifteen programs (21%) met all eligibility requirements (4 from internet searches, 11 from recommendations). A total of 55 programs failed to meet eligibility on one or more criterion (see Table A4). About three-fourths of programs failed to meet only one of eligibility requirements. Eleven programs failed to meet two of the criteria, and two programs failed to meet three of the requirements (see Tables A4 and A5).

Most (86%) programs that failed eligibility did so because evidence of effectiveness in the form of a peer-reviewed publication or an external evaluation report was not available. While we know that many of these programs receive federal funding or grants from other sources that require evaluation, reports are often submitted, retained internally, and not shared through websites or in peer-reviewed publications. Due to the

time limits and resources for this review, we had to rely on evidence of effectiveness that was publicly available rather than contacting individual programs for unpublished external evaluation reports.

The second most common requirement (29%) that programs failed to meet was a clear focus on teacher leadership preparation, learning, development, and/or support. In these cases, the abstract included “teacher leader”, but the program description did not focus on teacher leadership development. For example, in one case the program was for preservice teacher development, but the abstract included the phrase “work closely with local teacher leaders.” In another case, program goals included developing a “cadre of mathematics teacher leaders”, but the program primarily focused on (and measured effectiveness by) improving teachers’ mathematical content knowledge and pedagogical skills.

Eight programs (14%) had insufficient information available to clearly describe program goals, strategies, and outcomes. All programs met the systemic approach criterion except for one which was a university certificate program that had no connections with any district or local community K-12 schools (see Table A6).

Full Review

The full review process involved using the program materials to respond to predetermined categories designed to answer the research questions. All programs except for two (Hughes Science Grant and STELP) had more than one type of source material for the review. Five programs had two sources, five programs had three or four sources, and one program (Freshman Physics) had five different sources of information (see Tables A7 and A8). The program website (12), external evaluation reports (11), and peer-reviewed publications (6) were the most common sources of information. Other sources were the grant award website (3), other websites (2), non-peer-reviewed publications/presentations (2), participant materials (2), instruments (1), and an annual report (1). It should be noted that only peer-reviewed papers/presentations and external evaluation reports were used as sources for program findings. Non-peer-reviewed papers/presentations were only used for program description purposes. It should also be noted that the eligible programs included the Knowles Science Teaching Foundation, which employs the reviewer. The review process for KSTF was identical to other programs. The reviewer only used publicly available materials and did not add any insider information during the review.

The categories used for the full review were as follows:

- Program definition of leadership
- Program goals
- Program site (location, community demographics)
- Program participants (demographics, recruitment/selection, requirements)
- Program activities (participant experience, contact hours, topics, mode of delivery, program follow-up)
- Data collection/analysis (methods, by whom and when, instruments)
- Evidence of effectiveness
- Findings (program attributes of teacher leadership, context, program intervention, characteristics of teachers, informative to other contexts)

We used a form to enter information from program materials into each category for each program. Responses for each program are recorded in the program catalog at the end of this review document.

After entering the responses for each category, the entries were coded using QDAMiner software to allow for comparisons across programs. A descriptive coding process was used to summarize the main characteristics or topics from the program materials in each category. The codes were displayed and counted for each program and across programs to see similarities and differences. In order to provide a reference point for the teacher leadership definitions and roles, there were two additional layers of coding: first, using the domains of the Teacher Leader Model Standards (Teacher Leader Exploratory Consortium, 2011) and second, using Lukacs and Galluzzo's (2014) three models of teacher leadership. Similarly, program strategies received additional coding using research-based principles of effective professional development (Desimone, 2009).

Table A3: Search Results and Eligibility

Internet search				
Search location	Key words	Time period	# returns	# eligible
Google Advanced Search	-All in title: Math OR Science teacher leadership program -Verbatim	anytime	3	1
Robert Noyce Teacher Scholarship program advanced search	-Master Teaching Fellows	anytime	31	2
NSF EHR advanced search	-Teacher leader in abstract or title -Active projects	active	12	0
DOE MSP advanced search website	-Keyword leader; filtered using list of MSP projects that met criteria for rigorous evaluations and reviewed abstracts for teacher leadership	2010–2013	4	1
Internet search totals			50	4 (8%)
Recommendations from individuals, literature review, or program coding			20	11 (55%)
Total			70	15 (21%)

Table A4: Number of Programs that Did Not Meet One or More Eligibility Criteria

Number of eligibility criteria not met	Number of programs
1	42 (76%)
2	11 (20%)
3	2 (4%)

Table A5: Programs Not Meeting Specific Eligibility Criteria

Eligibility criteria	Programs not meeting eligibility*
The program supports math and/or science and/or STEM teachers	0
The program takes place within K-12 education	0
The program extends beyond the local level (single school)	0
The program takes a systemic approach (connected to, or takes into account, the contexts in which teacher leadership is enacted)	1 (2%)
Descriptions of program goals, strategies, and outcomes are clearly stated and described	8 (14%)
The program is focused on teacher leadership preparation, learning, development, support	16 (29%)
There is evidence of effectiveness provided in a peer-reviewed publication or external evaluation report	41 (74%)

*Does not add to 100% because some programs did not meet multiple eligibility criteria.

Table A6: List of Programs that Did Not Meet Eligibility Requirements

Program title	Program location/lead	Eligibility requirements not met
A Community of Problem Solvers: Teachers Leading Problem-Based Learning in Southern Illinois	Southern Illinois University	Evidence of effectiveness
Arizona Science Teachers Association Teacher Leadership Program	Arizona Science Teachers Association	Evidence of effectiveness
Cal Poly Pomona Master Teacher Fellows Program	California State Polytechnic University, Pomona	Evidence of effectiveness
Cal Teach at Berkeley: Robert Noyce Teacher Scholarship Program	University of California Berkeley	Focus on teacher leadership
California State University Dominguez Hills Master Teacher Fellows Program	California State University Dominguez Hills	Evidence of effectiveness
CEEMS: The Cincinnati Engineering Enhanced Mathematics and Science Program	University of Cincinnati Main Campus	Focus on teacher leadership
Center for Excellence in Math and Science Education Teaching Fellows Planning Grant	California State University Fullerton	Evidence of effectiveness
Collaborative Research: Cyber-enabled Learning: Digital Natives in Integrated Scientific Inquiry Classrooms	New York Institute of Technology, University of Connecticut, Boise State University, and Utah State University	Focus on teacher leadership
Collaborative Research: Marine Technology for Teachers and Students (MaTTS)	University of Connecticut and University of Rhode Island	Evidence of effectiveness
COSTEM, Colorado Champions for STEM Education Leadership Academy	BSCS	Evidence of effectiveness
CSUN NSF Teaching Fellowship Program	California State University Northridge	Focus on teacher leadership; Evidence of effectiveness
CSUSB Noyce Mathematics Teaching Fellows	California State University San Bernardino	Focus on teacher leadership; Evidence of effectiveness
Expert Teachers x Explicit Math Instruction = Exemplary Student Achievement	California State University (CSU) Fresno and Fresno Pacific University	Focus on teacher leadership

Program title	Program location/lead	Eligibility requirements not met
Fullerton Mathematics Teacher and Master Teacher Fellows (FULL MT2)	California State University Fullerton	Evidence of effectiveness
Gila Elementary Math Masters (GEMMs)	Central Arizona College	Focus on teacher leadership
Heritage University, Teacher Leadership, Math Specialist, M.Ed	Heritage University	Systemic approach; Evidence of effectiveness
I-IMPACT	Kennesaw State University, in partnership with the Georgia Institute of Technology	Evidence of effectiveness
Integrating Quality Talk Professional Development to Enhance Professional Vision and Leadership for STEM Teachers in High-Need Schools	Pennsylvania State Univ University Park	Description of program; Evidence of effectiveness
LaM3 (Louisiana M Cubed)	University of Louisiana at Lafayette	Evidence of effectiveness
Making Mathematical Reasoning Explicit	Washington State University and University of Idaho	Evidence of effectiveness
Math for America LA	University of Southern California	Evidence of effectiveness
Math for America San Diego Noyce Master Teaching Fellowship Program	University of California San Diego	Evidence of effectiveness
Math for America-DC	American University/Carnegie Institute of Washington	Evidence of effectiveness
Mathematical ACES: Algebraic Concepts for Elementary Students	University Enterprises Corporation at CSUSB	Description of program; Evidence of effectiveness
Mathematics Studio Fellowship Program - A Model for Mentoring New and Master Teachers	Oregon State University	Evidence of effectiveness
Mathematics Teacher Leadership Center Teacher Leadership Program	The University of Northern Colorado (UNC) and the University of Wyoming (UW) under the umbrella of the Mathematics Teacher Leadership Center (TLC)	Evidence of effectiveness
Mathematics Teacher Transformation Institutes	Lehman College Math Science Partnership (NSF)	Evidence of effectiveness
Michigan Teacher Excellence Program (MITEP): A Model for Improving Earth Science Education Nationwide	Michigan Technological University	Evidence of effectiveness
MTSU Master Teaching Fellows Project	Middle Tennessee State University	Evidence of effectiveness
NebraskaMATH: Robert Noyce Teacher Scholarship Program (NebraskaNOYCE)	University of Nebraska at Lincoln	Description of program; Evidence of effectiveness
Noyce Master Teacher Fellowship @ UCSD	University of California San Diego	Evidence of effectiveness
Noyce Math and Science Scholarships	California State University San Bernardino	Focus on teacher leadership; Evidence of effectiveness
NOYCE/MSTI Master Teacher Fellows Program	Xavier University of Louisiana	Evidence of effectiveness
Partnership for Ambitious Science Teacher Leaders (PASTL)	Puget Sound ESD, Olympic ESD, Northwest ESD, University of Washington	Evidence of effectiveness
Pipeline for Excellent Rural Teaching (PERT)	North Dakota State University Fargo	Focus on teacher leadership; Evidence of effectiveness

Program title	Program location/lead	Eligibility requirements not met
Puerto Rico Master Math Teacher Program	University of Puerto Rico at Rio Piedras	Evidence of effectiveness
Recruiting and Retaining Teacher Leaders in Physics and Chemistry	Kennesaw State University	Description of program; Evidence of effectiveness
Reinvigorating Elementary Science through a Partnership with CA Teachers (RESPeCT): Sustainable research-based professional development with teacher leaders in a high-needs district	Cal Poly Pomona Foundation, Inc.	Description of program; Evidence of effectiveness
Research on the Development of Computational and Systems Thinking in Middle School Students through Explorations of Complex Earth Systems	TERC Inc. and Northeastern University	Description of program; Focus on teacher leadership; Evidence of effectiveness
Rice Regional Science Collaborative / Houston	Rice University (Houston, Texas)	Focus on teacher leadership
Robert Noyce Scholarship Program	Dowling College	Focus on teacher leadership
Scaling Up Success: Using MATE's ROV Competitions to Build a Collaborative Learning Community that Fuels the Ocean STEM Workforce Pipeline	Monterey Peninsula College	Focus on teacher leadership
SDSU Noyce Mathematics and Science Master Teaching Fellowship Program	San Diego State University	Evidence of effectiveness
STEM-Plus	Louisiana Tech University	Focus on teacher leadership; Evidence of effectiveness
Tampa Bay Robert Noyce Master Teacher Fellows Program	University of South Florida	Description of program; Evidence of effectiveness
Texas Leadership Initiative: Mathematics Instruction Transformed (Texas LIMIT)	Stephen F. Austin State University	Evidence of effectiveness
The Academy for Leadership in Science Instruction	Merck Institute for Science Education	Evidence of effectiveness
The Poincare Institute: A Partnership for Mathematics Education	Tufts University	Evidence of effectiveness
The Science, Technology, Engineering, and Mathematics (STEM) Education and Leadership program	Illinois State University Technology Education	Focus on teacher leadership
The Teacher Leadership Program of the Park City Mathematics Institute	Park City Mathematics Institute	Evidence of effectiveness
The TEAM-Math Teacher Leader Academy for Elementary Mathematics Specialists	Auburn University	Evidence of effectiveness
The Wipro Science Education Fellowship	COSMIC Center; Montclair State University; Michigan State (separate programs)	Evidence of effectiveness
U-FUTuRES— University of Florida Unites Teachers to Reform Education in Science	University of Florida	Evidence of effectiveness
UMass-Dartmouth's TEACH! SouthCoast STEM	University of Massachusetts Dartmouth	Evidence of effectiveness
Urban Mathematics and Science Teacher Collaborative	Tufts University	Description of program; Focus on teacher leadership; Evidence of effectiveness

Table A7: Program Materials

Program title	Program website	Grant award website	Other website	External evaluation report or case studies	Peer-reviewed publication	Data collection instruments	Non-peer-reviewed paper / presentation	Participant materials	Annual report
Albert Einstein Distinguished Educator Fellowship (AEF) program	●			●					
Arizona Master Teachers of Mathematics	●	●			●				
Assessing Core Content and Ensuring Success in Science (ACCESS)		●		●					
Examining Mathematics Coaching (EMC)	●				●	●	●●		
Exploratorium Teacher Institute leadership program	●				●				
Howard Hughes Science Grant Montgomery Public Schools				●					
Kenan Fellows Program for Teacher Leadership (Model Three)	●		●	●				●	
Knowles Science Teaching Foundation's Fellows programs	●			●●●●	●				●
Leadership in Freshman Physics	●			●	●		●	●	
Math Science Partnership of Southwest Pennsylvania	●			●●					
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT)	●		●		●				
Mathematics Education Collaborative	●			●					
NebraskaMATH: Primarily Math	●	●		●					
Science, Technology, and Engineering Leadership Program (STELP)				●●					
Science: It's Elementary	●			●●					

Program Data Collection

Evidence for effectiveness varies in design, method, and data collection across programs (see Table A8). Nine programs use pre/post participant comparisons (generally using participant surveys), and five programs use comparison groups to measure effects. Most programs (9) use both quantitative and qualitative methods. Five programs use qualitative methods only, and one program evaluation (MEC) design uses only quantitative methods. Descriptive statistics are used most often (10 programs) to determine effects, with a smaller number of programs (5) employing inferential statistics for comparisons. One-half of the 10 programs that have pre-post or comparison group designs did not test for significant differences between groups but drew conclusions using only descriptive statistics. For qualitative analysis, the majority of programs (12) provide representative examples or quotes to support their findings but most often do not explain how they coded or selected the examples/quotes. Three programs utilize case study methods, four programs code the data using inductive methods, and one program uses deductive coding.

Participant surveys and interviews are the most common methods of data collection for detecting program effects on participants (see Table A8). Program documentation and artifacts are the primary data sources for assessing program quality and/or fidelity. Five programs include classroom observations of participants, and three programs include observations of participants' leadership activity. A few programs collect survey and/or interview data from a variety of sources other than participants, including program staff, supervisors/principals, colleagues, or recipients of teacher leadership activities (e.g., professional development attendees). The Kenan program includes a student survey, and Nebraska Math interviews parents as part of their evaluation. Three programs administer pre/post content knowledge assessments to their teacher participants. The Mathematics Education Collaborative is the only program that includes students' state test scores in its evaluation.

Table A8: Program Data Collection and Sources

Program data collection											Data sources																				
		Design		Quant.		Qual.		Coding			Surveys						Interviews					Observations			Program materials		Assess-ments		Other		
Program title	Number of studies/evaluation reports represented	Comparison group	Pre-post	Descriptive statistics	Inferential Statistics	Case study	Representative examples/quotes	Deductive	Inductive	Social network analysis	TL participant	Program staff	Teacher supervisor / principal	Colleague	TL recipient	Students	TL participant	Colleagues	Supervisor	Program staff	Parent	TL participant classroom	TL participant leadership	Program activities	Program documentation	Program artifacts	TL participant	Students	Post program leadership	Post program teacher retention reports	Advanced degree report
Albert Einstein Distinguished Educator Fellowship (AEF) program	1	●	●	●	●		●				●	●	●				●							●							
Arizona Master Teachers of Mathematics	1						●																		●	●					
Assessing Core Content and Ensuring Success in Science (ACCESS)	1	●	●	●	●		●				●						●					●		●	●	●	●				
Examining Mathematics Coaching (EMC)	1							●															●								
Exploratorium Teacher Institute leadership program	1						●																	●	●	●					
Howard Hughes Science Grant Montgomery Public Schools	1		●	●			●				●				●										●						
Kenan Fellows Program for Teacher Leadership (Model Three)	1		●	●			●				●	●	●	●		●									●				●	●	
Knowles Science Teaching Foundation's Fellows programs	5	●		●	●	●	●		●	●	●		●	●			●	●	●	●			●		●	●					

Program data collection											Data sources																				
		Design		Quant.		Qual.		Coding			Surveys						Interviews					Observations			Program materials		Assess-ments		Other		
Program title	Number of studies/evaluation reports represented	Comparison group	Pre-post	Descriptive statistics	Inferential Statistics	Case study	Representative examples/quotes	Deductive	Inductive	Social network analysis	TL participant	Program staff	Teacher supervisor / principal	Colleague	TL recipient	Students	TL participant	Colleagues	Supervisor	Program staff	Parent	TL participant classroom	TL participant leadership	Program activities	Program documentation	Program artifacts	TL participant	Students	Post program leadership	Post program teacher retention reports	Advanced degree report
Leadership in Freshman Physics	2		●	●			●		●		●														●	●					
Math Science Partnership of Southwest Pennsylvania	2		●	●	●	●	●				●						●		●	●		●	●	●	●		●				
Mathematically Connected Communities - Leadership Institute for Teachers (MC2-LIFT)	1						●																		●	●					
Mathematics Education Collaborative	1	●	●	●	●																	●						●			
NebraskaMATH: Primarily Math	1	●	●	●		●	●			●	●			●			●	●	●		●	●					●				●
Science, Technology, and Engineering Leadership Program (STELP)	2		●	●			●		●						●		●								●	●					
Science: It’s Elementary	2								●								●					●		●							